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PANDORA MOTH STUDIES IN LODGEPOLE PINE
ON THE ARAPAHO NATIONAL FOREST DURING 1939

By

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Forest Insect Laboratory,
Fort Collins, Colorado,
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PANDORA MOTH STUDIES IN LODGEPOLE PINE ON THE ARAPAHO NATIONAL FOREST DURING 1939

INTRODUCTION

The infestation of the pandora moth, Coloradia pandora Blake, in lodgepole pine on the Arapaho National Forest in central Colorado was first discovered in August 1937. Up to that time the insect was known chiefly as a pest of ponderosa pine in California and Oregon. The infestation on the Arapaho National Forest had the aspects of becoming very severe until this past season when natural factors reduced the population very greatly. General observations on the infestation during 1937 and a description of the insect and its habits were included in a report by J. A. Beal (1). Studies during 1938 were reported upon by N. D. Wygant (3). This report contains the observations and studies made during the summer of 1939 and also some of the notes from 1938. Mr. C. L. Massey, Agent, assisted in the investigations during June and part of July.

DESCRIPTION OF STAGES

Adults. The adults are brownish gray. The antennae are yellow, a little longer than the thorax, those of the males feather-like, and those of the females more slender but in both sexes they

are serrated on two sides. The thorax is covered with long soft black hairs and streaked with fewer nearly white hairs. The fore-wings are brownish grey, with an indistinct wavy, blackish band extending obliquely across them. Near the center of each wing is a distinct black spot. The hind wings are tinged with pink especially near the base and interior margin which in the males usually shades to deep pink.

Eggs. The eggs are about 2.5 mm. in length and 2 mm. in width, slightly compressed, typically ovoid in shape, and pale bluish green when laid, later changing to a duller green.

Larvae. The larvae are black or brownish when they emerge from the eggs and covered with short dark hairs. The full grown larvae are about 60 mm. long and yellowish green. There is a dorsal white stripe1 to 2 mm. wide that runs the full length of the body. Sometimes this white stripe is divided into two by a very fine black longitudinal line. On each side of this stripe to midway on the sides the larvae are regularly mottled with black. The amount of black varies with individuals from almost none to almost solid black. On segments 1-5 and on segment 10 are 8 black, branched spines. On segments 6-9 are 6 such spines.

Pupae. The pupae are dark chocolate brown and range in length from 25 to 35 mm. and in width from 12 to 15 mm.

BIOLOGY

Adults. The Colorado specimens from lodgepole pine are smaller than those found in California and Oregon. The average wing spread of 23 males was 75 mm. and the average of 37 females 81.5 mm. Patterson (2) gives the wing expanse of the males as 85 mm. and the females 96 mm.

The main emergence of the moths during 1938 was in July but a few stragglers continued to appear throughout the summer. Upon emergence the moths crawl up the trees and other objects before their wings have expanded. The males are attracted to the females and copulation may occur before the wings have expanded or dried. Copulation usually occurs on the trunk of the trees with the head of the female pointed upward. The males are better fliers than the newly emerged females but this may be due to the fact that the abdomens of the females are heavily loaded with eggs. The early flights of the females are of short distances such as from the ground to a tree or from branch to branch. On July 8 there were 176 male and 126 female moths on a tree 8 inches d.b.h. and 25 feet high. Of that total 80 moths were copulating. Female moths with dry unexpanded wings were quite common. These moths mated and laid their eggs the same as the other moths.

Numerous female moths were attracted to the blue neon lights in the towns of Granby and Hot Sulphur Springs, Colo., during July and early August 1938. Occasionally there was a male moth among the female moths. It is possible but not probable that the male moths migrate with the female moths and are not attracted to the lights. The red, green, and white lights were not nearly so attractive as the blue. Granby is approximately 12 miles and Hot Sulphur Springs approximately 11 miles from the known infestations. It is possible that these moths came from unknown infestations nearer to the towns. The moths probably were migrating or in flight and were attracted to the lights when passing over the towns. According to Patterson (2) in his studies with the pandora moth in southern Oregon and California, "The adults are strong fliers, and are strictly diurnal. In the writer's studies individuals could never be found active at night, nor could they be attracted to lights displayed in the forest after dark or before daylight." Patterson's failure to attract the moths to the lights was probably because he did not try blue lights or sufficiently bright lights.

Counts of the dead moths under 3 trees in the center of an infestation on August 3, 1938, substantiate the evidence that the female moths are longer lived and migrate from the infestations. Only 15 percent of the 232 dead moths were females. No counts have

been made to determine the sex ratio but it is believed that the two sexes are about equal in number.

Eggs. The eggs are deposited singly and in clusters of 2 to 50 principally on the branches, needles, and trunks of trees. The eggs develop in the pupae in the spring. Egg-laying may start the same day the moth emerges. The incubation period of the eggs was not accurately determined but it appeared to be approximately 40 days, the period determined by Patterson. The eggs started hatching the first part of August and by August 26 approximately 50 percent had hatched. By the last of September a few remained unhatched on the north exposures.

The average number of eggs in 27 females collected on July 8 that had not yet oviposited was 153.1. The average number of eggs in 50 females collected at a blue neon light in Granby, Colo., on August 2 was 19.7. The egg counts on the two groups are summarized in the following table:

Count of Eggs in Bodies of Moths

	Number Moths	Average Number of Eggs	Greatest Number Eggs Found in Moth	Smallest Number Eggs Found in Moth
Moths not having oviposited	27	153.1	187	109
Moths caught at light	50	19.7	97	0

Thirteen of the 50 moths caught in town contained no eggs and this lowered the average per moth considerably. If 153.1 is considered the average number of eggs produced by a female, the moths had laid 87 percent of their eggs before being attracted to the lights.

Larvae. The larvae started to hatch from the eggs during the first and second week in August 1938 and continued to hatch throughout the rest of the summer. By August 26 approximately 50 percent of the eggs had hatched. The larvae are gregarious during the first instar but during the second instar seldom more than 3 or 4 larvae can be found in a group. Table I shows the change during the season in the relative proportions of the five larval instars. The larvae overwinter on the branches at the base of the needles mostly in the second instar. A few overwinter in the first and third instar. Approximately the first of May 1939 they resumed feeding. By the last of June nearly all had reached the fifth and last instar. The larvae started to go to the ground to pupate about July 7. By the last of July all had pupated except for a few stragglers.

Table II shows the width of the head capsules of the 5 instars. The measurements were made to the nearest .001 inch with

an increment core measurer. The various instars are distinguishable in the field without the use of a hand lens by the relative sizes of the larvae.

Table I

Percent of Larvae in Each Instar at Various Times of the Season

Date of Collection	Total Number Larvae	Percent in Instars 1	2	3	4	5
Aug. 30, 1938	500	100				
Sept. 20, 1938	307	88	12			
Oct. 5, 1938	258	24	76			
Nov. 10, 1938	179	3	93	4		
May 19, 1939	568		11	86	3	
May 31, 1939	155			48	52	
June 6, 1939	141			19	81	
June 9, 1939	54			6	94	
June 12, 1939	52				90	10
June 15, 1939	36				75	25
June 20, 1939	113				50	50
June 27, 1939	62				6	94
June 30, 1939	74				4	96
July 7, 1939	71				1	99

Table II

Head measurements of *Coloradia pandora* larvae

Instar	Number Larvae Measured	Average Width of Head in .001 inch	Variation in Width in .001 inch
1	50	44.2	41.0-47.0
2	50	66.7	63.0-74.0
3	49	87.0	82.0-96.0
4	50	121.4	112.0-128.0
5	49	163.7	152.0-177.0

Pupae. Pupation occurs within 24 hours after the larvae enter the soil. The pupae are nearly always found in loose mineral soil. A few can be found in the soil beneath litter. The larvae apparently are unable to enter soil that is hard.

The pupae ordinarily remain in the soil over one winter and the adults emerge the following July. A small percent remain in the soil through the following summer and winter to emerge the second July. This makes a 3-year life cycle in some cases instead of the usual 2-year cycle. On the East Fork of the Troublesome Creek Ranger Johnson found as many as 10 pupae per square foot during the fall of 1938 that ordinarily should have produced moths the preceding summer. On the Buffalo Creek drainage the highest number of hold overs in any area examined was 3 to 4 per square foot. The moths from the pupae that remained in the soil for 2 winters emerged in July 1939. The moths were common throughout the area during July 1939 but probably less than 1 percent as numerous as during July 1938.

NATURAL CONTROL FACTORS

Winter mortality. Since the larvae overwinter in the second instar on the branches they are subject to rigorous winter weather conditions and predators. During the winter of 1938-39 the larvae

were reduced in number by at least 50 percent. According to inhabitants near the area it was one of the coldest winters in history. Unfortunately no official weather stations are near enough to the area for their records to be applicable. Low temperatures may have been responsible for the reduction but it is also possible that birds may have preyed upon the larvae when there was a shortage of other food.

Wilt Disease. A wilt disease was first noticed in the infestation on June 15 and subsequent to that date became more prevalent. The larvae affected by the disease turn orange brown in color and their body contents become liquid (Fig. 2). In this state the body wall ruptures very easily allowing the body contents to flow out. The diseased larvae have a tendency to crawl out on the terminal branches before they die. On two trees artificially infested with 100 larvae each there was a mortality of 62 percent in tree No. 1 and 58 percent on tree No. 2 with an average mortality of 60 percent during the period June 8 to July 14.

Diseased larvae were sent to Dr. S. R. Dutky of the Moorestown, N. J., laboratory, Division of Fruit Insects, who reported as follows:

"I have made microscopic examination of the remains of the dead pandora moth larvae. Although the larvae were too decomposed to permit any very definite conclusions to be drawn, it would seem

from the lack of bacteria or other micro-organisms in the cadavers, that the larvae died from causes other than microbial infection. In all but one case, not more than two bacterial cells per field were observed; a very small number considering the advanced state of decomposition.

"In all specimens a large number of small, refringent, spheroidal bodies were observed which appeared to be of crystalline nature. These were studied for their behavior toward fat stains, solubility in concentrated nitric acid, and appearance under polarized light, and staining reactions. The bodies did not stain with iodine, Sudan III, methylene blue, or picric acid, were insoluble in cold concentrated nitric acid, and were not doubly refracting (appeared dark under crossed polaroids). From their appearance and reactions, it appears likely that they might be "polyhedral" bodies and it is possible that the wilt disease and death of the larvae might have been due to a polyhedral virus disease. Since no tissue cells or blood cells were found intact at the time of examination, it was not possible to determine the origin of these refringent bodies which were present in large numbers in all of the nine specimens sent. In order to determine whether these bodies originated in the nuclei and are associated with the exciting cause of the disease, it would be necessary to examine a number of larvae, preferably living larvae. It would be well also to run a small number of infection tests using the body

fluids of dead larvae to contaminate the food of the test larvae and to inject others. It would be best to use pandora moth larvae for these tests, although larvae of one of the other saturnids common in this section might prove satisfactory as a test insect.

"It appears likely to me that the disease present among the larvae will prove to be a polyhedral virus disease, but in order to make a diagnosis of any certainty it will be necessary to have opportunity to examine living larvae and to attempt infection tests."

Since the pandora moth was in the pupal stage at the time the report was received, it was impossible to supply live larvae for additional study of the disease at the time.

Heat and Drought. The summer of 1939 was one of the driest and hottest in the history of Colorado. During July when the larvae were beginning to enter the soil the ground was very dry and hard, and because there was little evaporation from the soil at that time, surface and subsurface temperatures were abnormally high. The larvae usually seek loose mineral soils in which to pupate and such spots usually received the direct rays of the sun. Although air temperatures as measured in a Weather Bureau type weather station were never lethal, soil surface temperatures were very high. At the elevation of the infestation, 8800 feet, the sun is very intense. On July 11 at 10:30 the soil surface temperature

beside a larva that had just died was 138° F. and 1/2 inch below the surface 135° F. On the same afternoon at 2:30 p.m. just after a larva had successfully entered the soil the temperature at the soil surface was 102° F. and the temperature just below the surface was 100° F. On July 13 at 10:45 a.m. the temperature at the surface where several larvae had died was 142° F. and 1/2 inch below the surface was 124° F. When exposed to such high temperatures the larvae become very active for a few minutes and then become inactive and later die (Fig. 1). All the mortality at this stage may not be caused from heat alone. Sometimes the larvae would get half or more than half of their body buried and hit an obstruction. They would then seek another spot and start digging again. A number of larvae were observed which died from this exhaustion.

Eight samples of 36 square feet each were taken on July 14 and 15 of the number of dead larvae on the surface and the number of pupae in the soil (Table III). The lowest mortality in the 8 samples was 34 percent and the highest mortality 55 percent. The average mortality for the 8 samples was 44 percent, which probably is a fairly accurate figure for the whole infestation.

Beal in 1937 also noted that the ground was covered with dead larvae at many of the spots selected for pupation. He attributed their death to heat before they could dig into the soil. The dead

larvae he saw were greatly shortened or ball shaped and appeared to have reached the prepupal stage. The dead larvae on the soil surface during the past season were not ball-shaped but merely dried, flattened larvae.

Table III

Mortality of Larvae Entering Soil

Sample No.*	Date	Live Pupae	Dead Larvae	Percent Mortality
1	July 14	9	7	44
2	July 14	10	12	55
3	July 14	25	28	53
4	July 15	72	37	34
5	July 15	33	27	45
6	July 15	46	32	41
7	July 15	41	39	49
8	July 15	19	18	49
Total		255	200	Av.44

*Each sample taken in an area of 36 sq. ft.

Predators. During the fall of 1937 it was evident that squirrels and bears were destroying many of the pupae. In search of the pupae, the bears had overturned many flat stones and the squirrels had dug small conical-shaped holes in the ground. During July 1938 animal feces composed almost entirely of pandora moth eggs were found in the area. No birds have been observed feeding on the caterpillars.

Parasites. The pandora moth in this infestation has been unusually free from parasitism. From one caterpillar, which was the only record of parasitism, a number of braconids (Hopk. U. S. No. 31405-E) emerged but determination of the species has not been made.

POPULATION DENSITIES

Some preliminary studies were made to determine the population density necessary to defoliate a unit area. Ten trays 3 feet square made with lathe sides and muslin bottoms were placed under 10 different trees in the infestation on June 8, 1939. The droppings were measured each morning, when possible, except during several intervals when no one was in the area, with a glass cylinder graduated in cubic centimeters. On June 8 the larvae were just beginning the fourth instar. The feeding during the first two instars is almost negligible, and during the third it is small compared with the next two instars.

On June 7 two isolated lodgepole pine trees approximately 10 feet tall were caged by means of a large tray 6.5 feet square with 1" x 4" sides and muslin bottom (Fig. 3). A Tanglefoot barrier was placed on the inside of the sides of the trays to prevent the larvae that fell off the trees from escaping. In addition a curtain of 40" muslin was tacked to uprights around the tray to prevent the wind from blowing the droppings out of the trays. On June 8, 100 larvae in the fourth instar were placed on each tree. At weekly intervals the number of larvae were counted on the trees and the number of larvae unaccounted for (presumably larvae that had escaped) were replaced. Larvae that died from wilt were not replaced with new larvae. The droppings were measured each morning. Photographs were taken of the trees at the time the larvae were placed on them and again after the larvae had reached maturity.

The summaries of the dropping measurements are given in Tables IV, V, and VI. The figures are not to be construed as precise but as a general indication of the amount of droppings expected from a given number of larvae. The purpose of the experiment was to secure some preliminary data so as to be able to estimate the population densities in other areas if the infestation again builds up. The heaviest feeding was from June 22 to July 12 (Table IV). Very

little feeding is done until the temperature rises above 60° F. The period June 15 to 21 shows a decline in feeding over the period June 8 to 14 because of an unusually cold period that lasted from June 18 to June 22. The fact that the wilt disease killed 60 percent of the larvae on the trees made it impossible to determine accurately the average volume of droppings per larva (Table V). The 14.9 cc. of droppings per larva was determined by dividing the total droppings from the 2 trees by 200. This obviously does not give a correct figure of average droppings because there was a 60 percent mortality during the period that the excrement was measured.

Table VI shows the total droppings collected from each tray and the calculated number of larvae which produced the droppings. Only two trees, 3 and 6, showed any visible decrease in foliage density between June 8 and July 14. In fact some of the trees were more dense on July 14 because of the new foliage that had come out in the meantime. Figure 5 shows tree number 6 on June 8 and Figure 6 the same tree on July 14. This tree had an estimated average crown radius of 7 feet; therefore the ground surface covered by the canopy would be 154 square feet. If there were 53.3 larvae above the area of 9 square feet (Table VI) there would have been a total of approximately 911 larvae on the tree on June 8. Of this number 40 percent, or 364 larvae, probably reached maturity.

Table IV

Cubic Centimeters of Droppings Collected in Trays* Beneath Infested Trees

Period	Droppings From: Trees Nos. 1	2	Droppings in Trays Nos. 1	2	3	4	5	6	7	8	9	10
June 8-14	172	206	29	28	40	26	27	57	22	20	11	20
June 15-21	101	128	17	20	63	21	19	49	17	14	22	17
June 22-28	240	269	36	51	143	57	44	171	30	33	51	69
June 29-July 5	370	438	75	67	172	94	66	275	47	53	58	88
July 6-13	431	626	116	62	132	99	84	248	52	54	52	70
	1314	1667	273	228	550	297	240	800	168	174	194	264

*Trays 9 square feet

Table V

Droppings and Larval Mortality from Two Trees Stocked with 100 Larvae Each on June 8, 1939.

Tree No.	Total cc. Droppings	Number Larvae June 8	Number Larvae Reaching Maturity	cc. Droppings per Larva*	Percent Mortality
1	1314	100	38	13.14	62
2	1667	100	42	16.67	58
Average	1490.5	100	40	14.9	60

* The figures are based on the 100 larvae of the original stocking. The actual droppings per larva would be approximately twice these figures because of the mortality between June 8 and maturity.

Table VI

Droppings Collected in Trays 3 feet Square from June 8 to July 14 and Estimated Number Larvae in Area above Trays

Tray No.	Total cc. Droppings	Estimated Number Larvae above Trays on June 8 [1]	Estimated Number [2] Larvae Reaching Maturity
1	273	18.2	7.3
2	228	15.2	6.1
3	550	36.7	14.7
4	297	19.8	7.9
5	240	16.0	6.4
6	800	53.3	21.3
7	168	11.2	4.5
8	174	11.6	4.6
9	194	12.9	5.2
10	264	17.6	7.0

[1] Determined by dividing total cc. droppings by 15 cc., the average droppings per larva.

[2] Determined by multiplying the estimated number of larvae above the trays on June 8 by 40 percent, the percent survival.

EXTENT OF INFESTATION AND DAMAGE

The infestation was spread over a wide area with the heavy flight of moths in 1938, but as already mentioned the larval population was later greatly reduced by natural factors. As a result, feeding was so light during 1939 that an accurate determination of the extent of the infestation could not be made. The heaviest feeding during 1939 was on the ridge at the head of Buffalo Creek near Donut Pass and in a small area between Timber Creek and East Fork of the Troublesome Creek. There were very few larvae on Strawberry Ridge north of Tabernash.

On June 20, 1939, Robert Stevenson collected a moth in the vicinity of Estes Park, Colo. Dr. Craighead also collected a moth on August 3, 1939, near Jacob's Lake on the Kaibab National Forest in Arizona. A male moth was collected by J. L. Hoerner at Rocky Ford, Colo., in 1938. The species apparently is widespread in this region and builds up in population at infrequent intervals.

A survey the latter part of August 1939 of the heavily defoliated areas shows that approximately 4,000 trees had died during 1938 and 1939 as a result of defoliation in 1937. There are many more trees heavily defoliated that have not yet died. Most of the heavily defoliated trees failed to put on new needle growth this year. The sap of the defoliated trees just before death becomes sour and has a disagreeable odor. Some of the trees were attacked by Ips, ambrosia beetles, and other barkbeetles.

SAMPLE PLOTS

No new plots were established in the infestation during the past season. All trees that had died since the plots were established during 1938 were examined and marked during July 1939. At that time 62 of the total 1919 trees on the 6 plots had died. Each plot was photographed during the past season but the photographs are not included in this report because they do not show any change in foliage condition from the photographs taken the year before and included in last year's report.

SUMMARY

The infestation of the pandora moth in lodgepole pine on the Arapaho National Forest in central Colorado was first discovered in 1937. Since that time general observations and limited studies have been made in the area.

The insect has, as a rule, a 2-year life cycle, but a few individuals require 3 years. The main emergence of moths occurred in July 1938. The moths mate and lay eggs very soon after emergence. The eggs hatch in about 40 days. The larvae have a total of 5 instars. They passed the winter in the second instar and reached maturity during early July 1939. The mature larvae seek loose mineral soil and dig into the soil to a depth of 1 to 4 inches to pupate. They are overwintering (1939-40) in the pupal stage. The

eggs form in the pupae in the spring and the moths emerge in July. A small percent of the pupae remained in the soil through 2 winters (1937-38 and 1938-39) and the moths emerged July 1939.

There was at least a 50 percent mortality of the larvae during the winter of 1938-39 from probably abnormally low winter temperatures. A wilt disease killed approximately 60 percent of the larvae in the fourth and fifth instars. Affected caterpillars turn orange brown in color and their body contents become fluid. At the time the larvae were entering the soil, July 1939, 44 percent of the remaining larvae were killed by the effects of heat and drought.

REFERENCES

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2. Patterson, J. E. The pandora moth, a periodic pest of western pine forests. USDA Tech. Bul. 137, Oct. 1929.
3. Wygant, N. D. Pandora moth studies in lodgepole pine on the Arapaho National Forest during 1938. Office Report. March 24, 1939.

CC: Craighead (2)
Evenden
Keen
Miller

Fig. 1. Caterpillars killed by heat on surface of soil.

Fig. 2. A fifth-instar larva killed by a wilt disease.

Fig. 3. Tree No. 1 on June 8 when infested with 100 caterpillars.

Fig. 4. Tree No. 1 on July 14 after larvae had reached maturity.

Fig. 5. Tree No. 6 on June 8 with tray beneath to catch caterpillar droppings.

Fig. 6. Tree No. 6 on July 14 after an estimated 364 larvae reached maturity. Compare with above figure for amount of defoliation.